Marine route optimization

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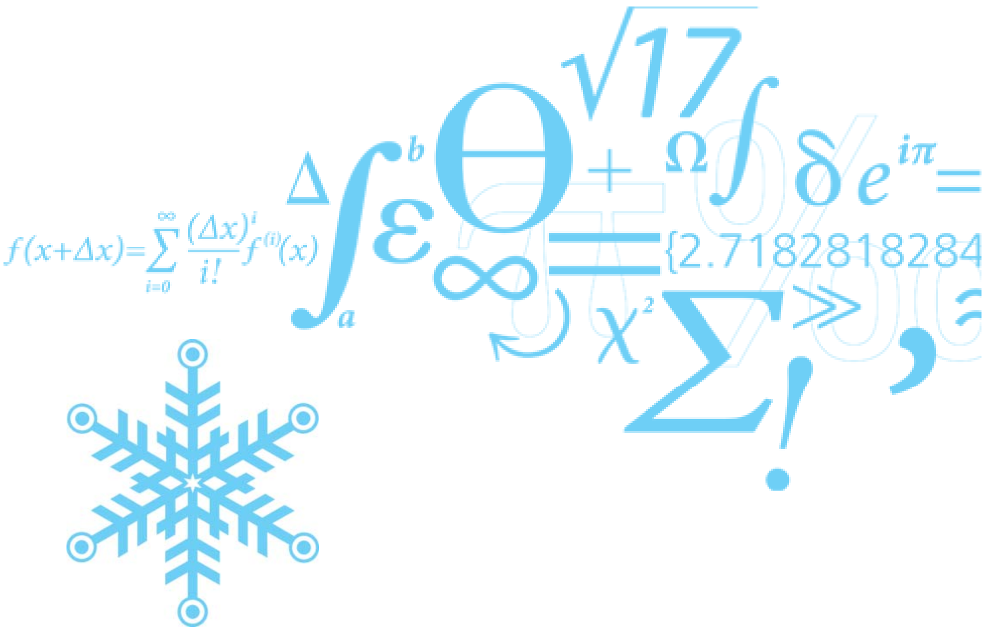


Polar DTU

Center for polare aktiviteter

Early attempt at route optimization

Jens Munk (1579-1628)

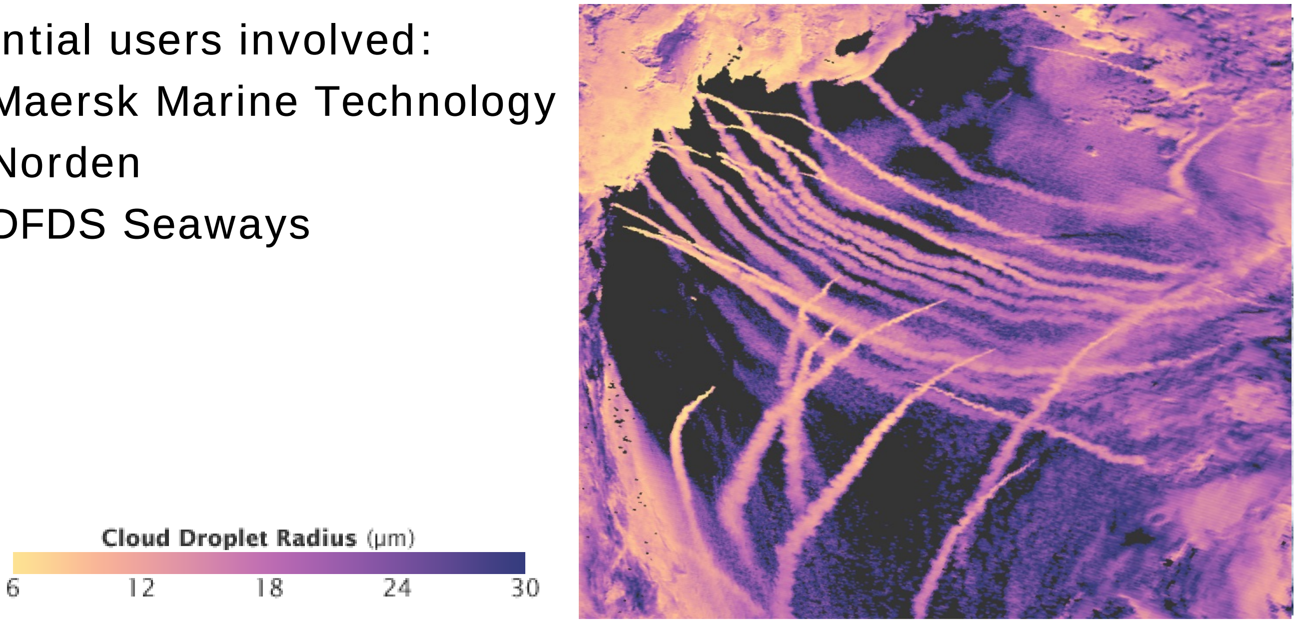
Tries to find a way to India through the North West Passage

Spends the winter 1619-20 in Hudson Bay.

Only 3 of his 64 men crew returns home.

BlueSIROS

- SIROS = Satellite Integrated Route Optimisation Service.
- "Near Real Time Marine Route Optimisation Service Integrating Satellite Derived Dynamic Ocean Currents".
- Collaboration between DTU Space, DTU Transport, DHI, Danish Defence Centre for Operational Oceanography and Danish Maritime Authority
- Application submitted to ESA
- Potential users involved:
  - Maersk Marine Technology
  - Norden
  - DFDS Seaways



March 4, 2009, northeast Pacific Ocean

Benefits of exploiting ocean currents

FIG. 173. — FRANKLIN'S CHART OF THE GULF STREAM.

Benjamin Franklin map of the Gulf Stream (1769)

Study objective

- Feasibility of an operational system for marine route optimisation, which integrates forecasts of ocean currents based on near-real time satellite altimetry data.
- Aim is to develop a framework for assimilating the real time satellite altimetry data into a route optimisation system.
- Enabling shipping companies to minimize fuel consumption, air pollution, and reduce fuel costs.

Altimetric Observations

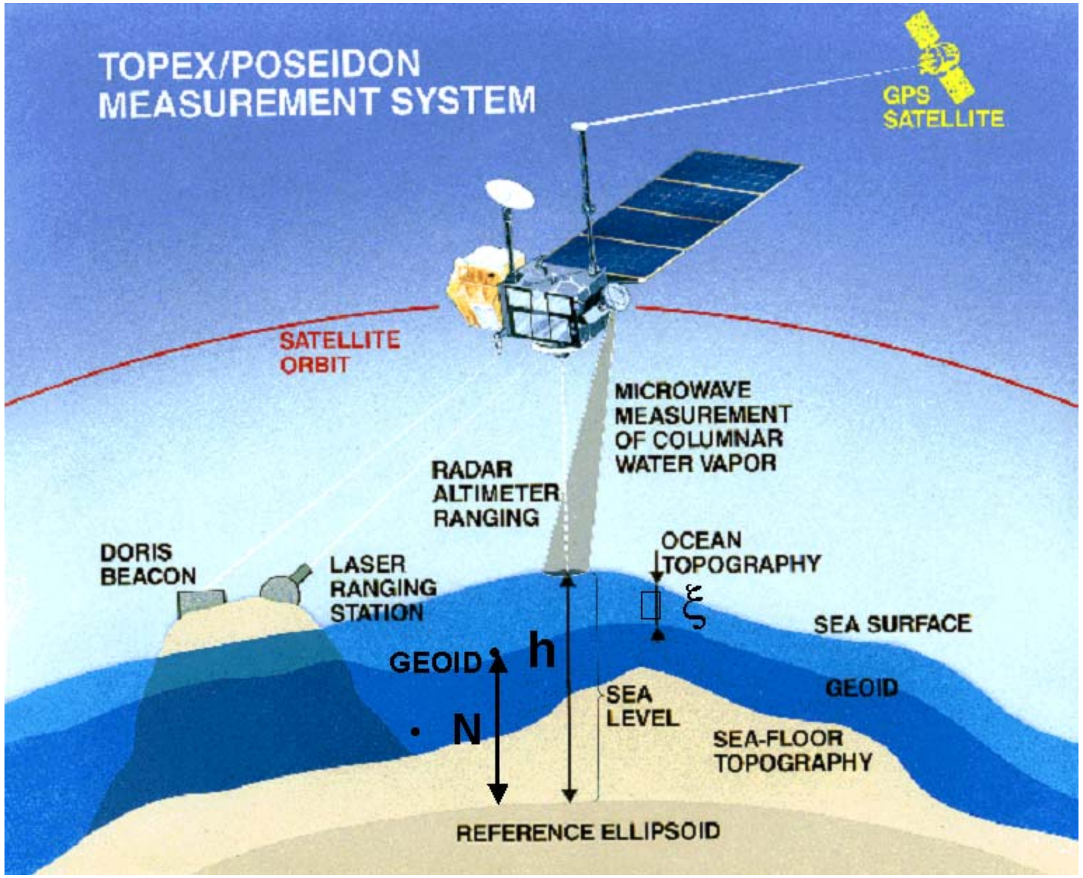
Accurate radar (or laser) ranging to the sea surface based on accurate time-determination $d = t * c / 2$

Where c must be adjusted slighly for propagation through ionosphere and troposphere.

$SSH = Height_{sat} - Range$

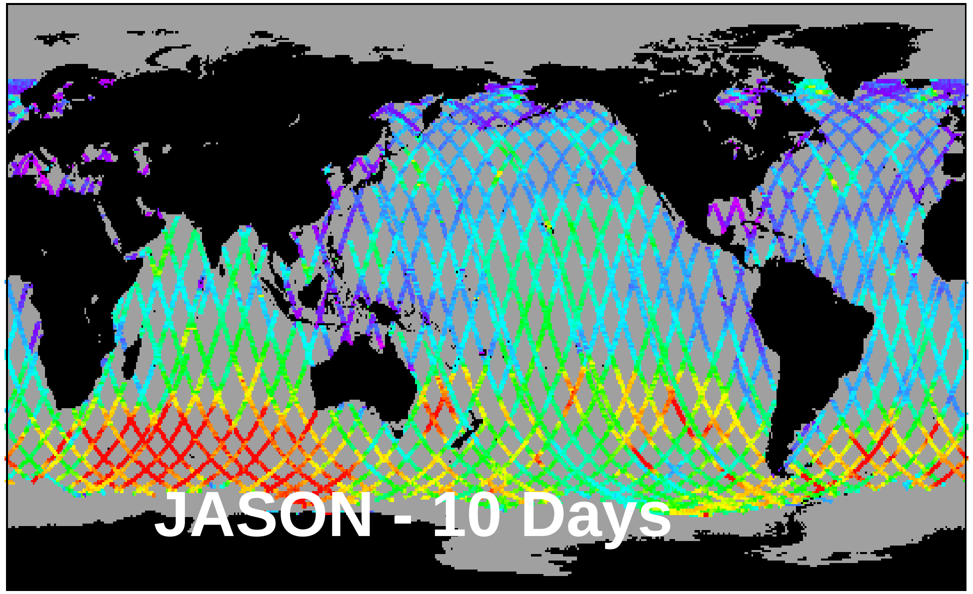
$Height_{sat}$ is determined using GPS

Ellipsoid is ”best” mathematical model of the Earth Shape



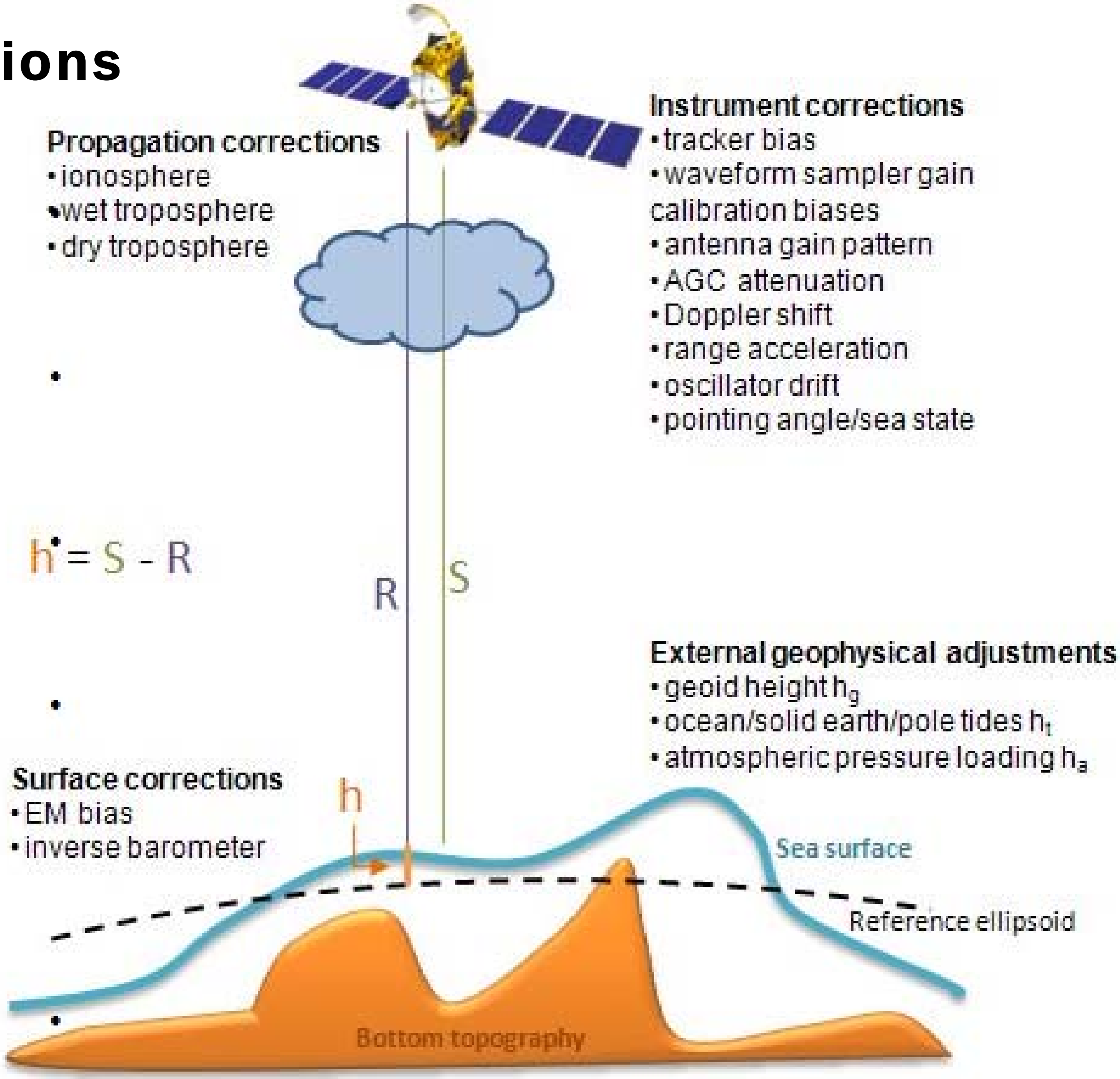
Orbit Parameters

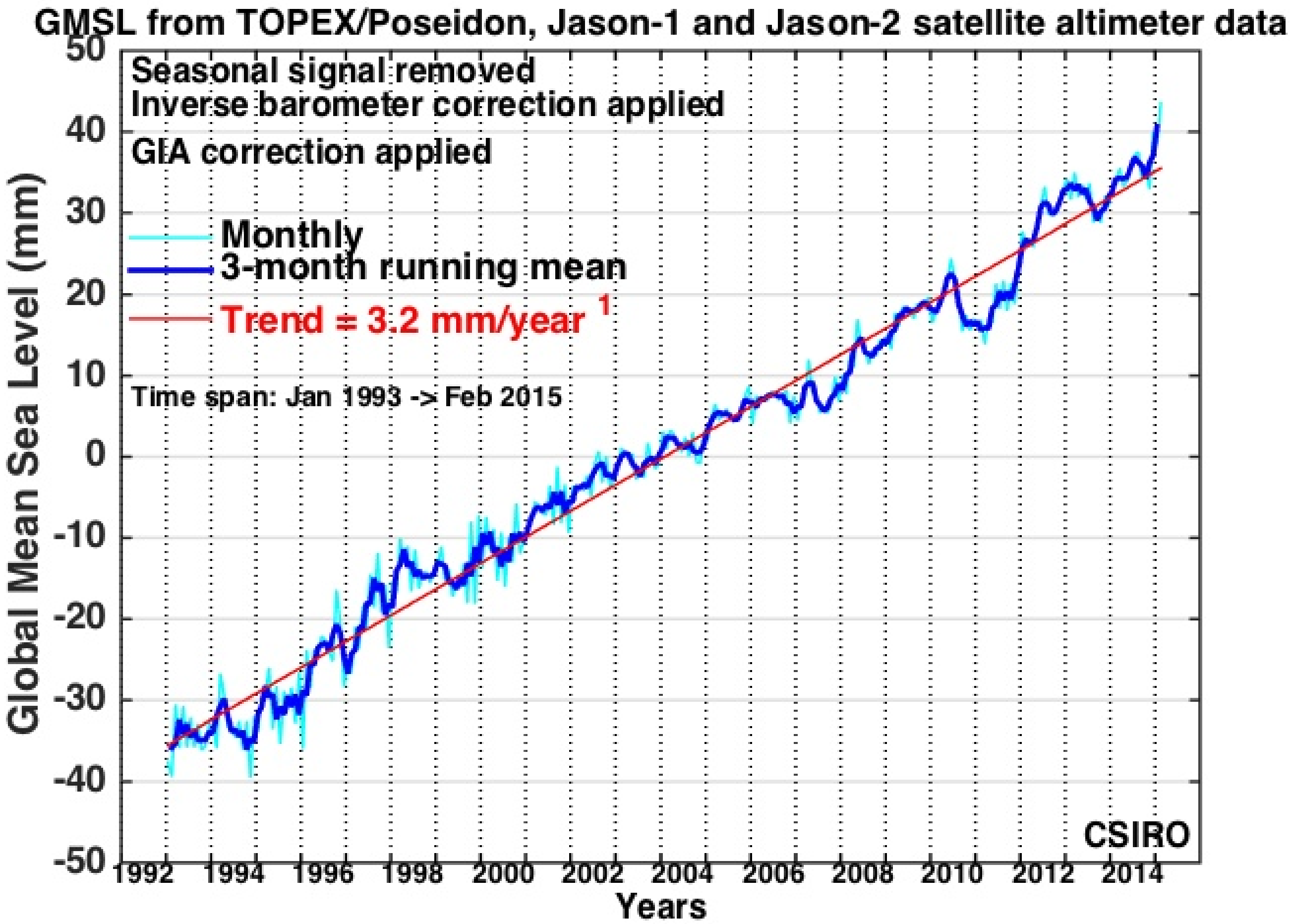
Coverage of sea surface depends on the orbit parameters (inclination of the orbit plane and repeat period).

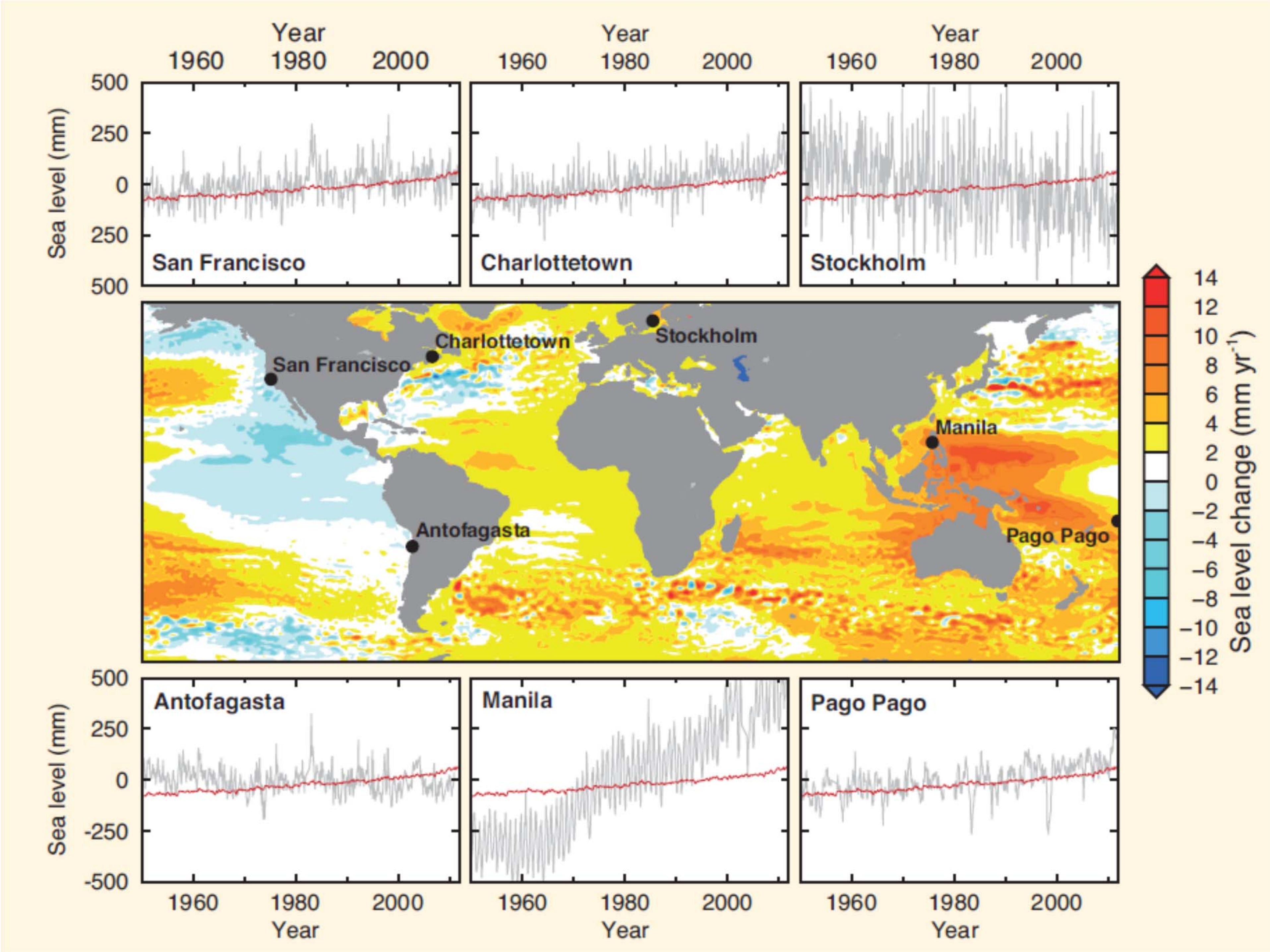


	Satellite	Repeat period	Track spacing	Inclination
Repeating (ERM)	ENVISAT/Sentinel-3	30 days	95 km	98°
	JASON 1-2-3	10 days	315 km	66.5°
Geodetic	Cryosat-2	369 days	7 km	88°

Corrections

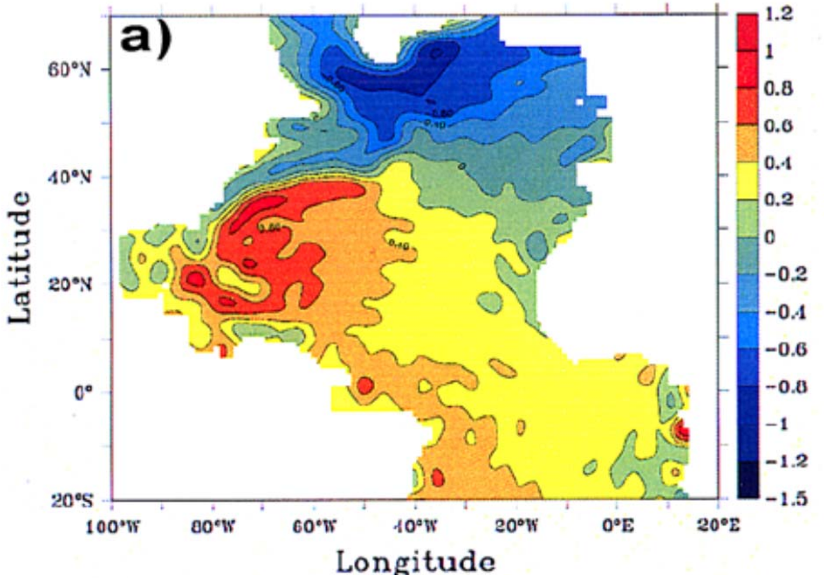



GMSL from TOPEX/Poseidon, Jason-1 and Jason-2 satellite altimeter data
Seasonal signal removed
Inverse barometer correction applied
GIA correction applied
Monthly
3-month running mean
Trend = 3.2 mm/year 1
Time span: Jan 1993 -> Feb 2015
CSIRO
Global Mean Sea Level (mm)
Years
50
40
30
20
10
0
-10
-20
-30
-40
-50
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

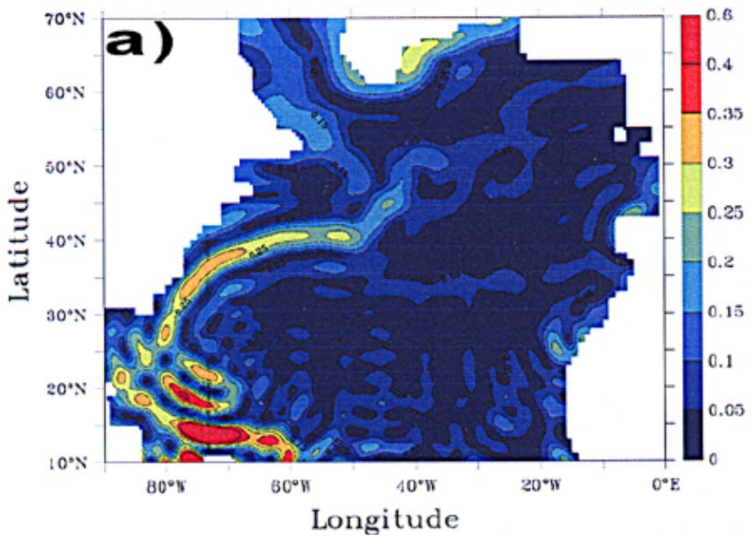

Year
1960
1980
2000
500
250
0
250
500
Sea level (mm)
San Francisco
Charlottetown
Stockholm
Antofagasta
Manila
Pago Pago
-250
-500
Sea level change (mm yr^{-1})
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14

Ocean currents

- Satellite altimeter: determines sea surface relative to reference ellipsoid
- Shape of sea surface -> information on geoid and the ocean circulation
- Ocean at rest: surface = geoid (+/- 100 m around ellipsoid)
- Ocean moves: surface deviates from geoid (+/- 1 m)
    -> information on tides and surface currents
- Resolution limited by shape of geoid

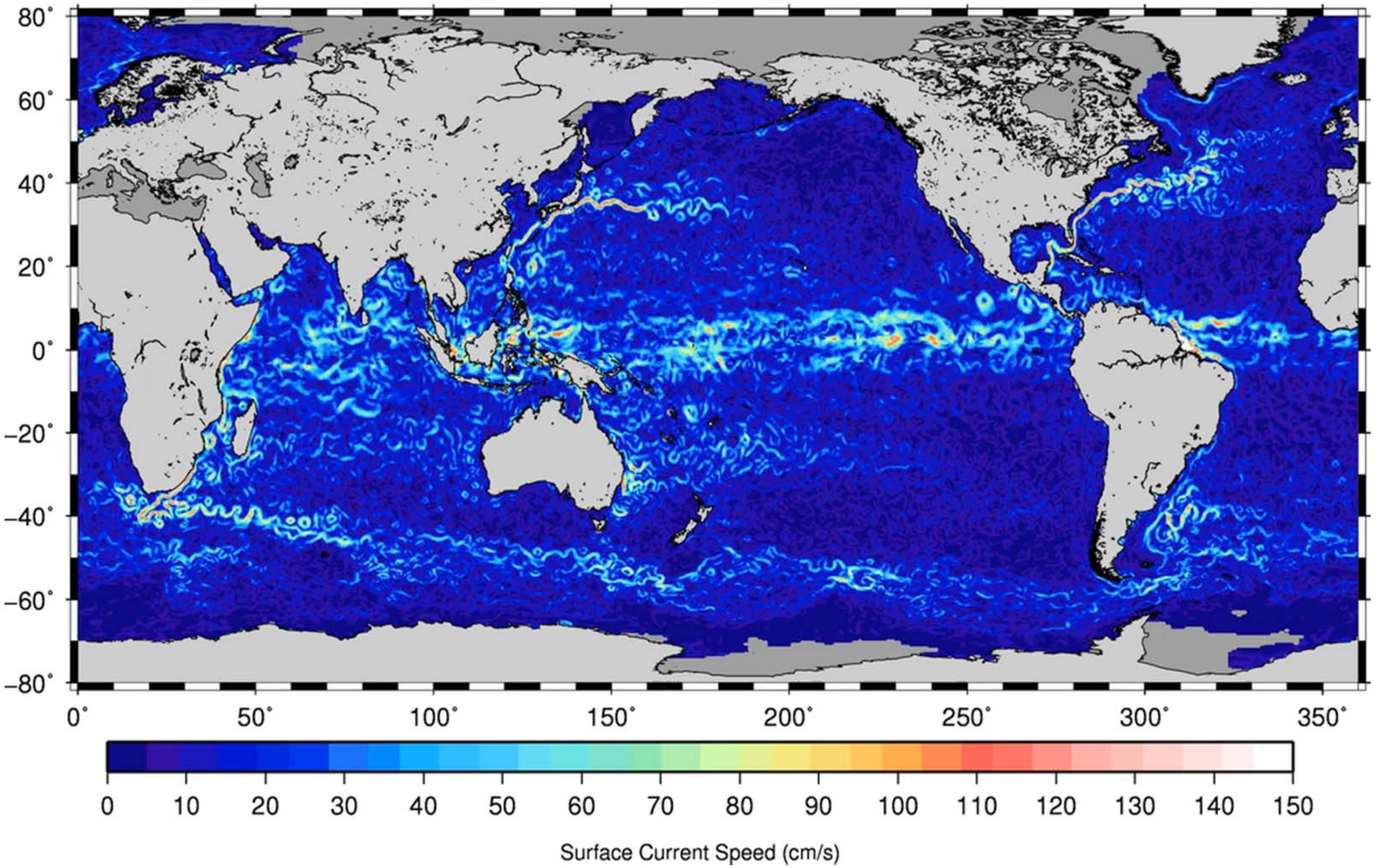


Topography (m)



Geostrophic currents (m/s)

12 30



80˚
60˚
40˚
20˚
0˚
–20˚
–40˚
–60˚
–80˚
0˚
50˚
100˚
150˚
200˚
250˚
300˚
350˚
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Surface Current Speed (cm/s)

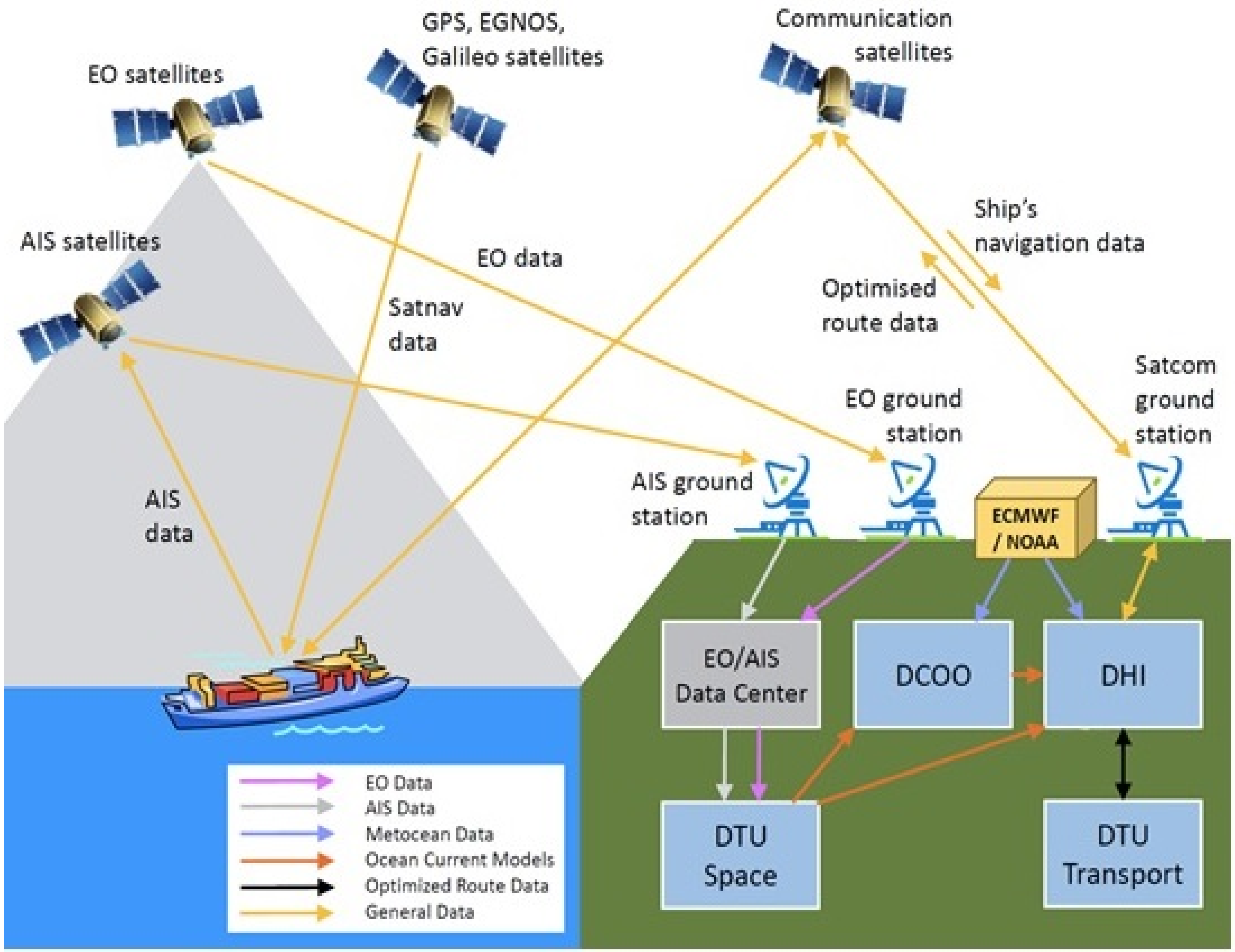
Data + models available:

- Near real-time estimates of currents, wind speed, and wave height
- Integrate in standard ocean modelling and forecasts
- Newly developed vessel drift model for bulk carriers for both deep and shallow waters: predicts the ships' behaviour encountering wind, waves and currents (inputs: geometric and operational characteristics of the ship, stability and hydrostatic data, ship position)
- Estimated savings on trans-atlantic route (average speed of 16 knots):
  – 7.5% when riding favourable currents
  – 4.5% when avoiding unfavourable currents

15 years of seafaring experience using weather routing:
– Reduced ship rough weather damages by 73%
– Costs of maintenance by 29 %
– Cargo damage lawsuits by 87%
– Length of ship delays due to unfavourable weather by 80%
– Fuel consumption by 6%

Challenges in the Arctic Region

- General metocean data less accurate
- Safety requirements for maritime traffic in the Arctic are higher (safety of the ship and its crew, and the environment)
- Defence Centre for Operational Oceanography (DCOO) represents a user with requirements for optimisation of complex operations during adverse conditions such as search and rescue operations.
- Low inclination of the Jason-2 & -3 orbits ($\approx 66^\circ$) preclude them covering the Arctic oceans. Only European Sentinels will be capable of providing EO information for marine route optimisation in the Arctic Ocean.
- Communication towards the ships has limited bandwidth, which may restrict the amount of information transmitted.


GPS, EGNOS,
Galileo satellites
Communication
satellites
EO satellites
AIS satellites
EO data
Satnav
data
Ship's
navigation data
Optimised
route data
Satcom
ground
station
EO ground
station
AIS ground
station
AIS
data
ECMWF
/ NOAA
EO/AIS
Data Center
DCOO
DHI
DTU
Space
DTU
Transport
EO Data
AIS Data
Metocean Data
Ocean Current Models
Optimized Route Data
General Data